THE EFFECTS OF THREE AUDITORY FREQUENCIES ON THE PERFORMANCE OF A SOUND LOCALIZATION MOTOR TASK

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Due to the lack of research regarding the quality of auditory cues used in devices for the visually impaired, the present investigation studied the effects of three different frequencies (1,000 Hz, 2,000 Hz and 3,000 Hz) on the performance of a sound localization motor task in the absence of visual cues. The sample consisted of fifty-eight normal male and female sixth grade students, who had achieved criterion performance on a pretest for throwing accuracy. The experimental task was performed blindfolded and involved throwing five test balls in an underhand action at a target with each of the three different auditory cues. The sequence of the three auditory cues was randomly determined for each subject. The results indicated that the 2,000 Hz and 3,000 Hz frequencies were better than the 1,000 Hz frequency for localization and that none of the frequencies used enhanced performance consistency over the others. The accuracy results showed that the 1,000 Hz frequency was perceived as being closer and as frequency increased (2,000 Hz - 3,000 Hz) the sound was perceived as being farther away. It is recommended, based on the present results that auditory devices that are used to aid the visually impaired in physical education activities involving sound location and accuracy performance should use frequencies of 2,000 Hz and 3,000 Hz in preference to the 1,000 Hz frequency.

This thesis is dedicated

to my parents

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Chapter 1

INTRODUCTION

The major objective of physical education programs for the visually impaired is to promote a higher degree of physical fitness through physical conditioning, activity skills, and better body mechanics. This will increase social competencies, improve psychological security to help the visually impaired face reality and gain confidence in the ability to function normally (University of New York, 1970).

In recent years advances in technology have been applied to help aid the visually impaired. A number of sensory aids have been developed that rely on either the tactile or auditory sense. Tactile aids were developed first, but more recently it has been found that auditory aids are more beneficial. These aids allow the visually impaired to move and relate to their environment, thus becoming more independent (Abel, 1957; Forrest, 1973). Sensory aids have also been developed to aid the visually impaired perform physical activities. Some examples of these aids are running cables, bowling rails, pinsetters, audible balls, goal locaters, and tandem bikes.

The auditory sense is the most useful and most used informational and educational channel the visually impaired possess (Goldish, 1968). The benefit of using an auditory cue in physical education programs and activities for the visually impaired is to improve motor performance. The research pertaining to the value of auditory aids in the performance of physical education activities for the visually impaired is scarce. Recently, Reid (1975) has demonstrated that the bowling performance of visually impaired subjects can be significantly improved by using an auditory cue. This auditory cue was a frequency of 900 hertz (Hz) which was produced by an audible goal locater. The selection of this frequency was based on a study by Wever (1949), who reported that phases up to 1,000 Hz permit easy judgment of sound direction. Hopefully by using an audible cue, a performance level will be reached, where the visually impaired can participate in physical recreation activities at or near the level of their normal peers.

After an extensive review of the literature pertaining to audible devices for the visually impaired, research could not be found related to what is the most appropriate frequency of the auditory cue to aid the visually impaired in physical activities. The major manufacturers of audible devices for the visually impaired also could not cite scientific research pertaining to the frequency selection used in their devices (refer to Appendix A).

Performance on accuracy tasks for the visually impaired is directly related to how proficiently the audible cue can be located. A person's ability to localize sound is dependent upon the differences in the time of arrival (phase) and the intensity of the sound (Minifie, Hixon & Williams, 1973). Therefore, localization of sound is dependent upon the intensity and frequency of the auditory cue (Stevens & Davis, 1938).

The human ear is sensitive to intensities ranging from one to 140 decibels (Newby, 1964). The ear is most sensitive to frequencies between 1,000 to 3,000 Hz. As frequency is moved above and below this range, increased intensity is required for the sound to be perceived. Within the frequency range that the ear is most sensitive, there exists a wide range of frequencies that serve as auditory cues. It is possible that within this range of frequencies, there exists a particular range of frequencies, that will serve as the most efficient auditory cues for the visually impaired performing sound localization tasks. Therefore, there is a need in the field of physical education for the visually impaired to determine what is the most efficient auditory frequency, when sound localization is necessary for proficient performance.

Statement of the Problem

This study was designed to investigate the effects of three auditory frequencies on the performance of a sound localization motor task.

Subproblems

1. What is the relationship between the three auditory frequencies and accuracy performance?
2. What is the relationship between the three auditory frequencies and consistency of performance within the individual?

Delimitations

1. This study is delimited to fifty-eight, sixth grade males and females, who attended Autumn Lane Elementary School in Greece, New York.
2. This study is delimited to the three frequencies used and the constant intensity presented.
3. This sample is delimited to subjects that had the ability to throw to a set criterion.

Limitation

There was no control for the amount of auditory training in sound localization of this sample.

Definitions or Clarification of Terms

For the purposes of this study, the following terms were used:

Auditory Frequencies - the three frequencies (1,000 Hz, 2,000 Hz, and 3,000 Hz) were used as the auditory cues for sound localization in this study.

Visually Impaired - individuals who must be educated through channels other than vision or require the use of special aids to capitalize on any residual vision.

Motor Task - a series of underhand throws with the dominant hand, aimed in the direction of an auditory cue, performed while blindfolded.

Localization Performance - was the ability to throw at an auditory target using only auditory information and was measured by the deviation in degrees the subjects throw was from the Y axis.

Accuracy Performance - was measured as the straight line distance in inches the subjects throw was from the sound source. This score was a composite of the subjects' horizontal and vertical errors. Under blindfolded conditions accuracy performance was dependent upon localization performance and past perceptions of distance.

Consistency Performance - was defined as the subjects' intra individual variability about their own mean for a particular frequency.

CHAPTER II

REVIEW OF THE LITERATURE

The literature reviewed in this chapter is divided into three sections. The first section is a review of the capacities and the terminology related to audition of the human ear. Section two is a review of the literature pertaining to the auditory modality of the visually impaired and normal individuals. The third section includes the review of literature pertaining to the effects of auditory cues on gross motor performance.

Capacities and Terminology

Sound is composed of three components: frequency, intensity and duration. Frequency is the number of cycles passing any given point in a unit of time. The unit of time that is used as a reference point is hertz (Hz) or cycles per second (Stevens & Davis, 1938). The human ear appreciates frequencies between 20 Hz through 20,000 Hz (Olson & Massa, 1939) and is maximally sensitive to frequencies between 1,000 Hz and 3,000 Hz (Gulick, 1971). As the frequency of a given stimulus increases, the amount that it has to increase to be perceived as a different frequency also increases. This differential threshold of the ear to perceive frequency changes does not increase with increasing frequency at a constant rate. It is negligible up to 1,000 Hz, then increases more rapidly (Minifie, Hixon & Williams, 1973).

Intensity is the magnitude of an auditory stimulus. This is the energy flow (power) per unit area. The human ear is sensitive to more than 100,000 different intensities (Gulick, 1971). Intensity is expressed in a decibel scale, which allows a large pressure range on a conveniently abbreviated scale. The decibel scale is based on logarithms and uses 0.002 dynes/cm^2, which is the weakest intensity the ear can perceive, as its reference point. The human ear is sensitive then to sound pressure levels from one to 140 decibels (Minifie, Hixon & Williams, 1973).

Finally, duration is the length of time a stimulus is presented. The ear's ability to hear a given stimulus decreases as the stimulus duration is decreased. To compensate for this decrease in our sensitivity we must increase the sound intensity. Duration is only a relevant variable with brief presentations (Minifie, Hixon & Williams, 1973).

Minifie, Hixon & Williams (1973) describe the ear's sensitivity to each of the three components in the following manner.

> The human ear is capable of discriminating frequency changes as small as one or two parts in a thousand, intensity changes one or two parts in a hundred, and duration changes one or two parts in ten (p. 377).

The human ear is most sensitive to changes in frequency (Shower and Biddulph, 1931). Therefore, the human ear is very proficient at discriminating frequency and rather crude at discriminating duration.

Localization of sound is the ability to describe the location of a sound based exclusively on auditory information (Minifie, Hixon & Williams, 1973). Localization of sound is most efficient when both ears are used. The cues used in sound localization are differences in time of arrival and the intensity of the stimulus that reaches each ear. For frequencies below 1,500 Hz there will be a difference of a few milliseconds in the time of arrival of the sound at each ear. Time of arrival is the most efficient cue for sound localization of these frequencies. For higher frequencies, where the half wave length is less than the distance separating the ears, there is an averaging process that occurs. For short wave high frequency sounds the head casts a shadow which causes the sound to be louder in one ear. Therefore, intensity becomes the more efficient cue for sound localization of high frequency sounds (Stevens & Davis, 1938).

Auditory Modality of the Visually Impaired and Normals

Previous research findings (Axelrod, 1959; Yates, Johnson, & Starz, 1972; Hare, Hammill & Crandell, 1970; Simpkins, 1971) failed to show any significant differences between the hearing acuity of the visually impaired and normal subjects. Morris, Nolan, and Phelps (1973), as well as others (Riley, Luterman, & Cohen, 1964), have demonstrated that hearing is the most useful sense the visually impaired possess with regard to education, rehabilitation and mobility.

Hare, Hammill, and Crandell (1970) studied the auditory discrimination ability of thirty pairs of visually impaired and sighted subjects. These subjects were matched for chronological age and intelligence quotient. The auditory task involved discriminating whether pairs of sounds were the same or different (Irwin, 1963). The results failed to show any significant relationship between visual acuity or the degree of sight and the ability to discriminate sounds.

Yates, Johnson, and Starz (1972) obtained similar results in their study of loudness perception of twenty blind and twenty sighted adults. The auditory task involved making comparative judgments whether the presented stimuli was louder or softer in comparison to a constant intensity. The stimuli were presented under binaural earphone conditions. The results indicated that there was little to no significant difference between the blind and sighted subjects for overall equal loudness contours within any single frequency or across any of the sound contours.

The relationship between hearing threshold and mobility performance is another aspect of audition that directly concerns the visually impaired. Riley, Luterman, and Cohen (1964) studied this relationship using twenty-seven recently acquired visually impaired adults who ranged in age from seventeen to fifty-eight, with a mean chronological age of thirty-eight. Each subject's hearing was tested to determine their hearing threshold. All subjects were legally blind and were blindfolded during mobility training to control for differences in residual vision. The purpose of their study was to find the correlation between hearing threshold and mobility performance. The Spearman Rank Correlation Coefficient was used to analyze the data. A significant relationship between auditory thresholds and mobility performance for visually impaired subjects was reported, using the .01 significance level. The investigators also stated that hearing is the most important exteroceptive sense remaining to the visually impaired person.

Morris, Nolan, and Phelps (1973) more recently studied the relative efficiency of the auditory media on academic achievement. The sample used was fifty-six visually impaired students from grades five through twelve. Both recorded and textual materials in English, Math, Social Studies, Physical Science and Language were utilized. No significant differences were found with regard to the quality of the learning. The recorded forms were found to allow 155% to 360% greater quantity of learning to occur over the same period of time when compared to textual materials. Also, 83% of the students involved in the experiment stated a preference for the recorded materials in the areas of English and Social Studies.

Lydon and McGraw (1973) have stated that the human ear can be trained for more éfficient sound conceptualization. This involved training in the areas of awareness, identification, localization and discrimination. Simpkins (1971) has shown that specific factors of auditory perception can be improved through training. The sample for this study consisted of fifty-five visually impaired students with normal hearing from kindergarten through third grade. Fourteen subjects were randomly selected initially and were given the pretest. Fourteen different subjects were randomly chosen at the end of the study for the posttest. Environmental sounds, language without story, and language and story (involved auditory memory) were the three specific areas tested. Unfortunately the author failed to describe these areas in more detail. All fifty-five subjects received fifteen minutes of training twice a day for six weeks. Auditory training only significantly improved the area of environmental sounds. Language and story showed no training effect. Language without story approached but did not reach significance.

In summary, there is no significant difference between visually impaired and normal subjects' ability to discriminate and perceive loudness of auditory stimuli. Also there is a significant relationship between auditory threshold and mobility performance of visually impaired subjects. In the area of academic achievement, it has also been found that the auditory modality is preferred and also increases the quantity of learning that can be obtained in a given period of time for the visually impaired. Finally, specific factors of auditory perception can be improved through training.

Effects of Auditory Cues on Gross Motor Skill Performance

There is a scarcity of literature pertaining to the effects of auditory cues on the performance of gross motor skills by normals and the visually impaired (Reid, 1975). The research concerning the normal population has dealt mostly with the effects of visual cues on gross motor skill performance. There have been a few studies that have dealt with the effects of rhythmic cues on motor performance (Dillon, 1952; Beisman, 1964). Docherty (1972) however, has studied the effects of auditory cue masking on normal subjects' accuracy performance. Reid (1975) has recently studied the effects of auditory cues on the bowling performance of the visually impaired.

Docherty (1972) tested eighteen (sighted) varsity tennis players under three different sound conditions: controlled sound, reduced sound, and masked sound. During the controlled sound condition subjects wore a modified earmuff that permitted them to hear the auditory cues normally. During the reduced sound condition, subjects wore a modified earmuff that reduced the sound cues by six to eight decibils. During the masked sound condition the subjects wore a headset through which white noise was transmitted at a sufficient intensity to mask all sound cues. The auditory cues were the sound of the ball hitting the racket, hitting the wall and rebounding from the court surface. The tasks used were a wall rally test for accuracy and a singles game like task. Subjects were allowed to use any strokes they preferred. Each subject performed the wall rally test four times and the game situation once. Data was obtained from questionnaires (concerning the auditory conditions) and from the accuracy scores on the two tests. Analysis of variance with repeated measures was used to analyze the data. The results were all nonsignificant. The investigator concluded that sound cues associated with these tasks seem to have little effect on the performance of varsity tennis players. This study did have two shortcomings: (1) only a small sample of highly skilled performers were tested and (2) the investigator failed to check the auditory acuity of the subjects.

Reid (1975) studied the effect of auditory cues on the bowling performance of the visually impaired. The sample consisted of thirty visually impaired subjects ranging in age from eleven to twenty-one years. These subjects were randomly assigned to a sequence of bowling tasks. The tasks involved bowling with and without the cue supplied by an audible goal locater. The results demonstrated that the audible goal locater significantly improved the bowling performance of acquired and congenitally blind subjects. The investigator concluded that the use of an audible goal locater can significantly improve the bowling performance of the visually impaired.

Summary

A review of the literature has revealed several important findings. First, sound localization is dependent upon intensity and frequency and that the ear is most sensitive to frequencies especially between 1,000 Hz and 3,000 Hz. Second, there is no difference between visually impaired and normal subjects with regard to hearing acuity. Third, it has been asserted by a number of authors that the auditory modality is the most useful sense that the visually impaired have with regard to education, mobility and rehabilitation. Finally, auditory cues can aid in improving the motor performance of the visually impaired in physical activities.

CHAPTER III

METHODS AND PROCEDURES

There have been numerous auditory devices developed to aid the visually impaired to participate in physical activities which involve the ability to localize sound. Audible balls have been used to help the visually impaired baseball fielders locate the ball. Audible goal locaters have been used to aid bowling performance and to designate goals in sports like soccer, hockey, and basketball. Very little research, other than Reid (1975), has been conducted concerning the value these devices have on motor performance. Due to the lack of research in the field of physical education with regard to the qualities of these auditory cues and their effects on motor performance, the following investigation was conducted.

This chapter is composed of four sections: (1) explanation for subject selection criterion; (2) description of the motor tasks used in the pretest and actual testing; (3) explanation of the testing apparatus; and (4) description of the administration and testing procedures.

Subject Selection

The subjects for this study were fifty-eight, sixth grade males and females who attended Autumn Lane Elementary School, in Greece, New York. School records were critically reviewed to assure that all subjects had normal hearing, intelligence, and no physical limitations that could effect performance on the test tasks. Normal subjects were selected based on the research findings that report that there is no significant difference between the hearing acuity of the visually impaired and normal subjects

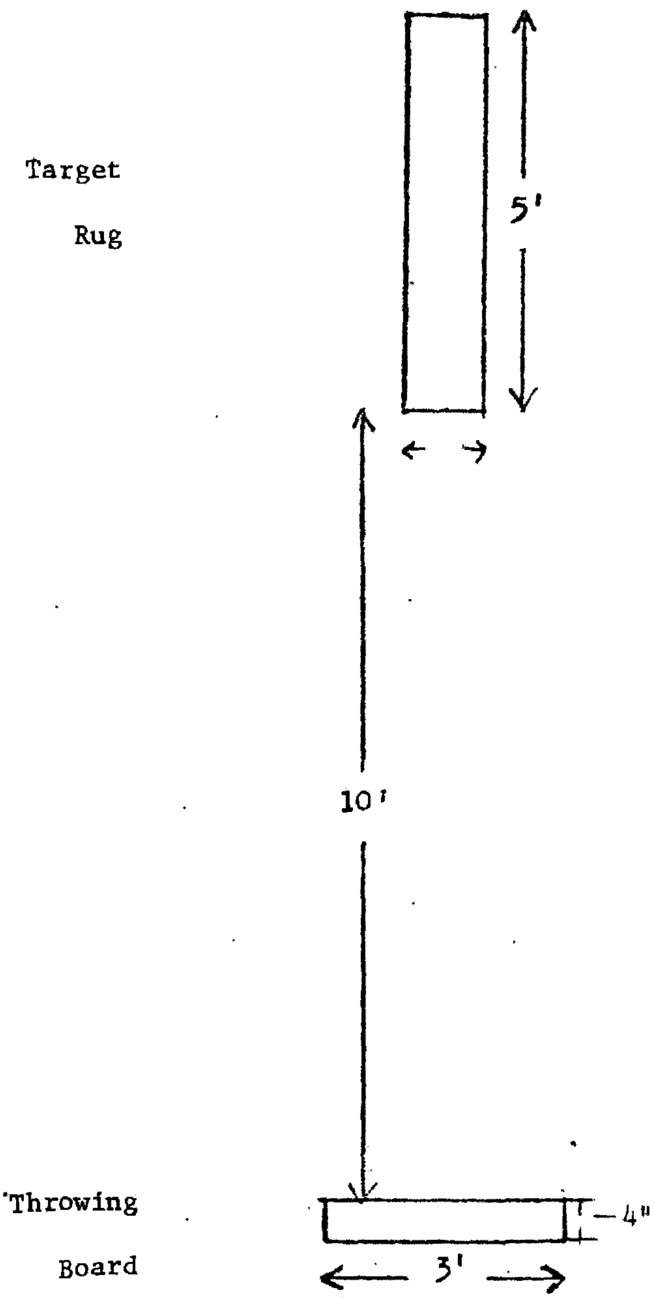
(Axelrod, 1959; Hare, Hammill, & Crandell, 1970; Simpkins, 1971; Yates, Johnson, & Starz, 1972). By using normal subjects a larger more homogeneous sample could be obtained with regard to age, ability and experience. All subjects in the sample reached a criterion performance level on the pretest. All prospective subjects were blindfolded during the actual motor task to eliminate all visual cues. All prospective subjects received the same instructions and performed both the pretest and test tasks. Subjects that did not achieve criterion performance on the pretest were not counted as part of the sample and their test task data was not collected. These subjects were treated the same as the actual sample subjects so as to maintain uniformity and reduce feelings of failing across the test population.

Motor Tasks

The pretest involved throwing a fluff ball in an underhand action, for two sets of ten throws, at a designated target. The target for the pretest was a strip of rug fifty-six inches long and seven inches wide, which was located on the floor perpendicular and ten feet in front of the perspective subjects (Figure 1). The dimensions of the target rug, the number of trials, the number of throws per trial and the distance of the throw for the pretest were determined from the results of a pilot test. All subjects in the sample were required to hit the rug at least twelve times out of twenty. This pretest was designed to serve three purposes. First, it assured that all subjects had an equal opportunity to experience throwing the test ball (a fluff ball). Second, it eliminated all subjects with poor throwing performance, which could have diminished the results of this study. Third, it assured that all subjects were able to throw the test ball in an underhand action at least ten feet.

Figure 1

Illustration of the Pretest Environment



The kinesthesiometer[1] (Figure 2) is a piece of apparatus that consists of a trough (which the arm is laid in) and a displacement scale marked in one degree increments from zero to 180 degrees. This piece of equipment is commonly used in motor learning studies investigating: (1) kinesthetic acuity in replicating previous movements, (2) measuring performance with the use of kinesthetic cues only, and (3) studying the effects of kinesthetic practice on learning and kinesthetic response consistency (Carron, 1971). The kinesthesiometer was used in this study to obtain a localization score for each frequency which was not dependent upon a complex motor skill (underhand throw). The kinesthesiometer was positioned so that it was thirty-eight inches high, in line with the subjects' throwing shoulder and pointing straight ahead at the sound source. All subjects were instructed as to how to place their arm on the kinesthesiometer, how it worked, and what they would have to do during the test task.

The motor task consisted of throwing five test balls, in an underhand action, at each of three different cues (frequencies) emitted from a target speaker. The object of this task was to try and throw the balls so that they landed as close to where the cue was coming from as possible. All subjects performed the motor task blindfolded. All three frequencies were emitted from the exact same place. The sequence of the three frequencies was varied randomly from subject to subject. The rationale for the distance of the sound source and the number of throws per frequency was determined from the results of a pilot study.

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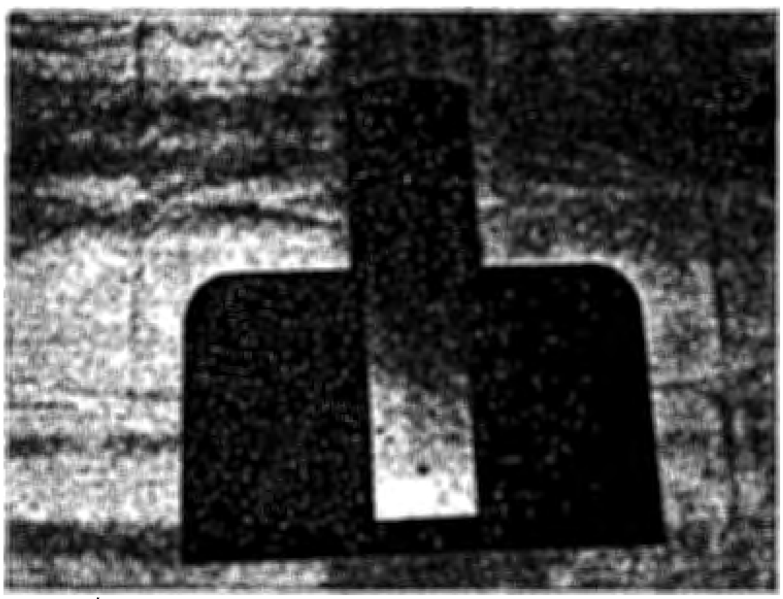
[1]Manufactured by Lafayette Instruments Company, Eastern Regional Office, 2116 Allen Str., Allentown, PA 18104.

Figure 2

Photograph of the Kinesthesiometer



Testing Environment

For this study, fluff balls were used to control for the differences in previous experience with regard to standard balls and to maintain uniformity across all subjects. The actual testing took place in the subjects' elementary school gymnasium. The sound source for this study was a Wollensak[2] 2520AV cassette player and recorder. This tape deck operated on 120 AC current and was capable of emitting frequencies over the range of 10 Hz to 10,000 Hz with minimal distortion. The tapes used were TDK Super Avilyn[3] cassette tapes. The volume was set so that the sound being perceived at the throwing board was approximately 40 decibels. The sound was emitted from an Olson[4] S-453 trumpet speaker. The speaker was located at ground level fifteen feet in front of the throwing board facing the subject. The speaker was placed on the origin of the X and Y coordinates. The X and Y axises formed four quadants which were sixteen feet by sixteen feet and were sectioned off into three inch intervals to allow for fast accurate scoring. Swimming goggles[5], which had the lenses painted with black enamel paint were used for blindfolds. The throwing board was a three foot by two foot "T" composed of two by fours, which was located fifteen feet from the origin and parallel to the X axis (Figure 3). The rationale for selecting the above dimensions and distances

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[2] Mincom Division, 3M Company, 3M Center, St. Paul, Minnesota 55101.

[3] TDK Electronics Corporation, Long Island City, New York 11103.

[4] Olson Electronics, Akron, Ohio 44308.

[5] Snitz Manufacturing Company, 2069 South Church Street, East Troy, Wisconsin 53120.

were determined from the results of a pilot study. The three frequencies used in this study were: (a) 1,000 Hz, (b) 2,000 Hz, and (c) 3,000 Hz. These three frequencies were selected based on Gulick (1971), who reported that the ear is maximally sensitive to frequencies between 1,000 Hz and 3,000 Hz. Based on a pilot study it was determined that 1,000 Hz, 2,000 Hz and 3,000 Hz represented three distinct frequencies within this range.

Administration and Testing Procedures

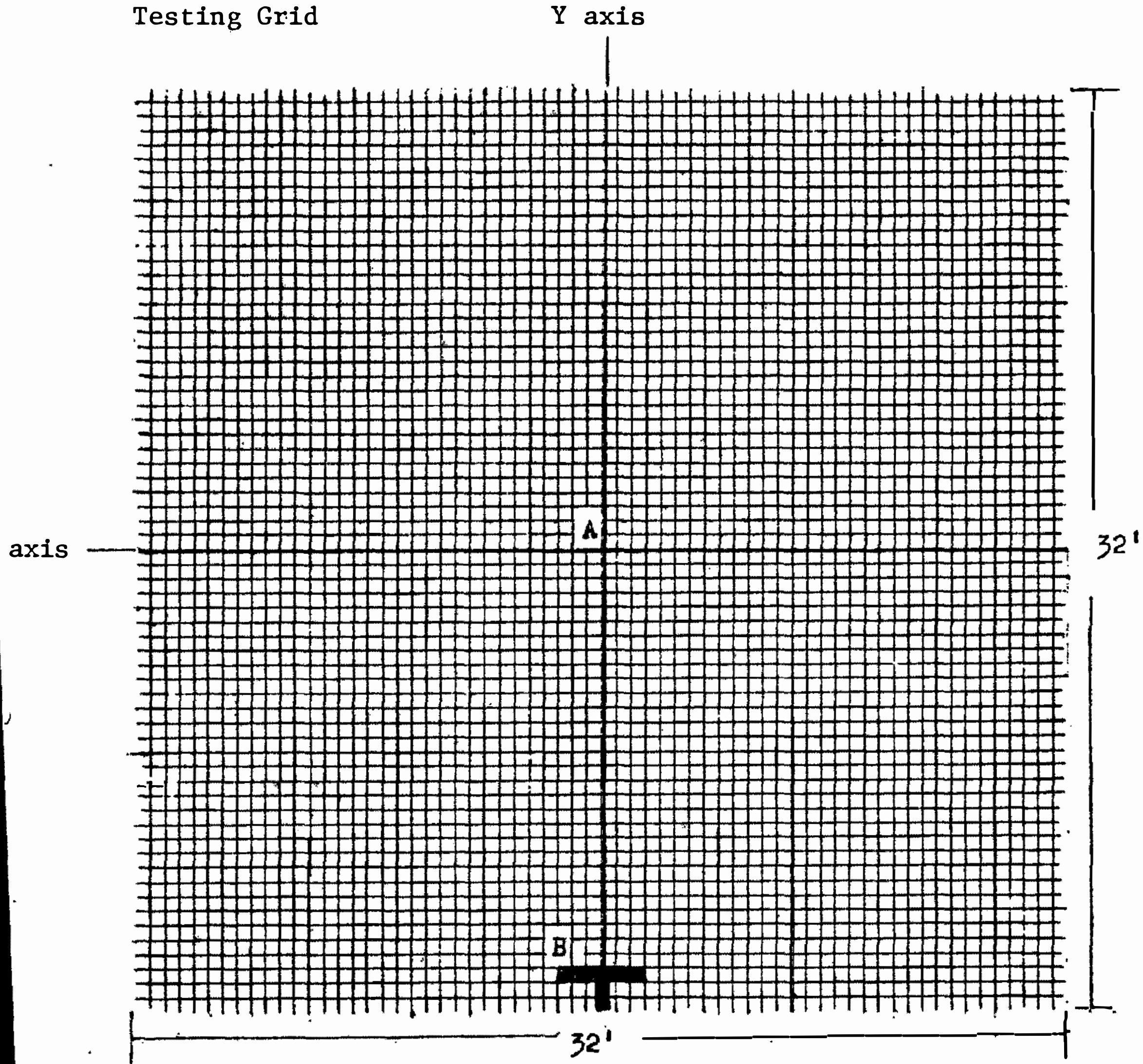
Testing was conducted in the spring, when physical education classes were being conducted outdoors and the gymnasium was available. Subjects were randomly assigned a time at which to report to the pretest area. The pretest was conducted in a closed off corridor and required approximately three minutes to administer. Following the pretest the subject was escorted by the investigator to the gymnasium, where the test task was administered. The administration of the test task required approximately seven minutes. The gymnasium was set up so that no one could enter or see the test apparatus during the testing period. Three days were required to conduct the study.

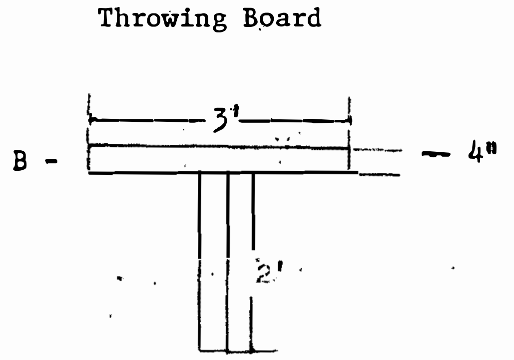
The following instructions were read to each subject prior to the pretest:

> Hello, my name is Mr. Kelly and I am from the State University of New York College at Brockport. I have come here to see how well the students in your grade can throw on two throwing tasks I have developed. I have tried to develop tasks that will be challenging to students your age. At the end of the two throwing tasks I would like you to tell me what you thought about them.

Figure 3

Illustration of the Grid Utilized in the Motor Task Testing Environment





A - Sound Source

> For this first task, I want you to throw balls like this one (a ball is shown) at the brown strip of rug in front of you on the floor. I want you to try and come as close as you can to hitting the rug on each throw. There are three rules that must be followed in order for your throws to count: (1) You must throw the balls from behind this board, (2) You must throw the balls in an underhand action (a demonstration is given) so that the ball lands on the rug without bouncing first, (3) You must use the same hand for all of your throws. You will have twenty chances to throw, try and hit the rug as many times as possible. Do you have any questions? After the tenth throw the subject was told "You are doing very well, you have ten throws left."

The following instructions were read to each subject after the completion of the pretest:

> You did very well on this task, you hit the rug (the scoring aide tells the subject their score). I think you will enjoy the second task I have for you. The next task will be conducted in your gym. In this task, instead of throwing at a strip of rug, I am going to have you throw at three different sounds. First you will point at the sound by placing your arm on this tray (the subject does this) and pointing it to the place you think the sound is coming from. Then I will move this tray out of your way and you will get to throw five balls like these (a ball is shown) at each sound. You will have to point and throw five balls at each of the three different sounds. Do you have any questions? There is one trick that makes this task a little harder. You will have to wear a blindfold. After you put this blindfold on I will lead you down to the gym and stand you in front of a board similar to this one (pre test board is referred to). Then I will explain the second task again. Are you ready? There is one new rule that you must obey. You cannot remove or touch the blindfold until I tell you.

The following instructions were read to each subject prior to the second task.

> The throwing board is directly in front of you now. Can you feel it with your feet? For this task the balls must be thrown from behind this board, in an underhand action (like before) and using the same hand. First, I will play a sound in front of you and you will point to where you think it is by placing your arm in this tray. Then I will remove the tray and you will throw five balls at that sound. You will do this same procedure for each of the three different sounds. The object of this task is to try and throw the balls so that they land as close to where the sound is coming from as possible. Do you understand? Put your arm on the tray. You are now pointing straight ahead. Are you ready? Here is your first sound.

At the end of the second task the subjects were lead blindfolded out of the gym. This was done to prevent the subjects from seeing the test apparatus. The blindfold was then removed, the subject was told that he/she had done very well and was asked what they thought about the two tasks. The investigator then escorted the subjects back to their corridor and explained that the outcome and details of the study would be explained on Friday afternoon.

One male undergraduate student aide assisted the experimeter in the administration of the pretest. This aide stood at the end of the rug and recorded whether the throws hit or missed the rug. This aide also randomly selected a tape and set it up for the second task. One female physical education graduate student served as an aide and assisted the experimenter with the administration of the second task. This aide first marked the spot where the ball landed with the appropriate colored and numbered chip. A particular color and numbers were assigned to each of the three frequencies. After the subject threw all fifteen throws, this aide computed and recorded the location of the chip in relation to the X and Y axis. All of the above procedures were done without verbal communication. The experimenter directed the aides nonverbally and gave the instructions to the subjects.

CHAPTER IV

ANALYSIS OF DATA, RESULTS AND DISCUSSION

This chapter is divided into three sections. The first section contains the analysis and results of the localization data. The second section describes the analysis and results of the accuracy data. The final section deals with the discussion of the localization and accuracy results.

Analysis and Results of the Localization Data

The localization scores were computed by drawing a horizontal line from the point where the throw landed so that it intersected the Y axis at a right angle. A second line was drawn from the point where the throw landed to the center of the throwing board. These two lines, plus the portion of the Y axis from the throwing board to the horizontal line, formed a right triangle. The subjects' localization score was then calculated in degrees by using the trigonometric formula , tangent of an angle equals the opposite arm (horizontal arm) divided by the adjacent arm (portion of the Y axis). This measurement in degrees represented the magnitude of the deviation from the Y axis.

The absolute error of the subjects' localization scores was examined. Subjects' raw mean localization scores for each frequency, which represents the magnitude of the discrepancy from the Y axis, are presented in Appendix B. Means and standard errors for the absolute error localization data are presented in Table 1.

It can be seen in Table 1 that (1) the 1,000 Hz frequency averaged 19.29 degrees from the Y axis, (2) the 2,000 Hz frequency was 15.27 degrees from the Y axis and (3) the 3,000 Hz frequency was 11.96 degrees from the Y axis. To determine if the three treatment frequencies absolute error scores were significantly different from one another a repeated measures design was employed. An assumption that had to be met before using the univariate repeated measures design was that the correlation between all pairs of the treatment conditions for each subject be constant. A test for homogeneity of covariance was not performed to test this assumption. The Geisser-Greenhouse conservative F test degrees of freedom was utilized to control for the possibility that the variances and covariances were heterogeneous (Kirk, 1968). For the repeated measures analyses that were performed in this study the .05 level of significance was chosen giving a critical F ratio of 3.07 for (2,114) degrees of freedom. However, since a test for homogeneity of covariance was not performed the conservative degrees of freedom (1,57) were used giving a critical F ratio of 4.00 at the .05 level of significance. Table 2 indicates that there was a significant difference between the three frequencies.

As a result of the significant finding the Neuman-Keuls post hoc procedure was employed to determine which frequencies differed from each other. The results of this analysis showed that (1) the 3,000 Hz frequency scores were significantly different in localization performance from the 1,000 Hz frequency and (2) the 2,000 Hz frequency scores were not significantly different from either the 1,000 Hz or the 3,000 Hz frequencies.

Table 1

Means and Standard Errors for Absolute, Constant and Variable Error of the Localization, Kinesthesiometer and Accuracy Scores for the Three Treatment Frequencies (n = 58)

	Treatment	Mean	Standard Error
Localization			
Absolute Error	1,000	19.29	14.90
	2,000	15.27	11.36
	3,000	11.96	13.42
Constant Error	1,000	6.83	22.32
	2,000	0.52	16.65
	3,000	-3.94	16.19
Variable Error	1,000	127.31	269.43
	2,000	131.45	359.57
	3,000	75.49	165.06
Kinesthesiometer			
Constant Error	1,000	10.19	28.40
	2,000	4.33	23.80
	3,000	-3.79	19.07
Accuracy			
Absolute Error	1,000	92.22	49.50
	2,000	87.80	43.24
	3,000	73.90	46.19
Constant Error Horizontal Scores	1,000	19.98	66.99
	2,000	1.77	56.92
	3,000	-7.90	44.31
Variable Error Horizontal Scores	1,000	1030.75	1619.69
	2,000	1209.53	3720.63
	3,000	687.60	1470.45
Absolute Error Horozontal Scores	1,000	58.68	42.70
	2,000	51.62	37.46
	3,000	36.01	32.99
Constant Error Vertical Scores	1,000	3.41	70.68
	2,000	14.87	69.42
	3,000	20.92	66.82
Variable Error Vertical Scores	1,000	779.01	887.50
	2,000	514.25	1011.97
	3,000	417.51	453.23
Absolute Error Vertical Scores	1,000	58.81	42.01
	2,000	58.82	41.41
	3,000	55.59	42.90

Table 2

Analysis for Repeated Measures Design for Absolute Error of Localization Scores for Each of the Three Treatment Frequencies

Source	DF	SS	MS	F
Treatment (A)	2	1565.28	782.64	6.06
Subjects (S)	57	15571.50	273.18	
AS	114	14704.62	128.98	
Total	173	31841.42		

Traditionally absolute error has been considered a measurement of accuracy. It has been accepted and widely used in this role because of its apparent logical simplicity. By examining the localization absolute error means, presented in Table 1, it might be concluded that the 3,000 Hz frequency was the most accurate. Based on the repeated measures analysis it could be concluded that the 3,000 Hz frequency was significantly more accurate than the 1,000 Hz frequency. Actually, absolute error is not a measure of accuracy, but is a measure of consistency. Absolute error represents the average absolute deviation from the mean (Schutz & Roy, 1973; Schmidt, 1970; and Henry, 1974).

Absolute error was computed by taking the sum of the difference between the performance score and the correct target score, without regard to sign. The sum of the differences was then divided by the total number of scores minus one. This measurement represented the magnitude of the average absolute deviation from the mean. Constant error was computed by taking the sum of the differences between the performance score and the correct target score, keeping the scores plus and minus signs. The sum of the differences was then divided by the total number of scores minus one. This measurement represented the magnitude and direction of the subjects' response bias. Variable error was computed by taking the sum of the squared deviations from the mean of the performance scores for each treatment and dividing by the number of scores minus one. This measurement represented how consistent each subject was about their own mean (intra individual variability).

Woodworth (1938) and Schutz and Roy (1973) have stated that constant and variable error should be analyzed instead of absolute error. Their argument is based on the fact that (1) constant and variable error statistically represent two nonredundant, non overlapping sources of information and (2) both constant and variable error allow for interpretation of the source of error. Absolute error is a composite of constant and variable error and does not allow interpretation of the source of error. Based on the above information the localization and accuracy data were analyzed for constant and variable error. Absolute error has also been presented for comparison with data of other studies that have only employed this measurement.

Constant error is an indicator of the subjects' response bias. It takes into consideration both the magnitude of the error and the direction (+ or -). A minus sign indicated that the score represents a throw to the left of the sound source and a plus sign indicated the score represents a throw to the right of the sound source (refer to Figure 3, page 20). The constant error means and standard errors for the localization data were presented in Table 1.

The mean scores show that the 1,000 Hz frequency was 6.83 degrees to the right, the 2,000 Hz frequency was 0.52 degrees to the right and the 3,000 Hz frequency was 3.94 degrees to the left of the sound source. To determine if the three treatment frequencies constant error scores were significantly different from one another a repeated measures design was employed. It can be seen in Table 3 that there was a significant difference between the three frequencies.

Table 3

Analysis for Repeated Measures Design for Constant Error of Localization Scores for Each of the Three Treatment Frequencies

Source	DF	SS	MS	F
reatment (A)	2	3399.85	1699.92	4.51
ubjects (S)	57	16240.41	284.91	
S	114	42887.17	376.20	
otal	173	62527.44		

As a result of the significance indicated by the repeated measures alysis, a post hoc analysis was employed to determine which frequencies differed from each other. The Neuman-Keuls post hoc procedure was utilized for this purpose. The results showed that (1) the 3,000 Hz frequency was significantly different from the 1,000 Hz frequency, but was not significantly different from the 2,000 Hz frequency and (2) the 2,000 Hz frequency was not significantly different from either the 1,000 Hz or the 3,000 Hz frequency.

An examination of the means presented in Table 1 indicated that the 2,000 Hz frequency was the most accurate, varying only .52 degrees to the right of the sound source. The results of the repeated measures and the Neuman-Keuls post hoc analysis indicated that the 2,000 Hz frequency was not significantly different from either the 1,000 Hz or the 3,000 Hz frequency. The Neuman-Keuls post hoc analysis did indicate that the 3,000 Hz frequency was significantly different from the 1,000 Hz frequency. This significance was a result of the subjects' tendency to throw to right on the 1,000 Hz frequency and to the left on the 3,000 Hz frequency. Based on this information it is suggested that there is a trend favoring the 2,000 Hz frequency over the 3,000 Hz frequency, but it was not a significant difference. The large experimental error due to various sources of variance may have made it hard to show significant differences.

Variable error is a measure of how consistent (intra individual variability) each subject was about their own mean. Variable error was examined to determine if there was any relationship between the three frequencies and the individual subject's consistency performance. The variable error means and standard errors for the localization data are presented in Table 1.

To determine if the three treatment frequencies variable error scores were significantly different from one another a repeated measures design was employed. It can be seen in Table 4 that there were no significant differences between the three frequencies regarding variable error.

Table 4

Analysis for Repeated Measures Design for Variable Error of Localization Scores for Each of the Three Treatment Frequencies

Source	DF	SS	MS	F
Treatment (A)	2	112812.90	56406.45	0.85
Subjects (S)	57	5582523.01	97938.98	
AS	114	7477854.01	65595.20	
Total	173			

An examination of the means presented in Table 1 indicated that the performance on the 3,000 Hz frequency was the most consistent. The repeated measures analysis showed that this performance was not significantly different from either the 1,000 Hz or the 2,000 Hz frequencies. The present results indicated that none of the frequencies used (1) significantly enhanced performance consistency over the others and (2) variable error mean scores do not support the trend indicated in the constant error results.

A kinesthesiometer was utilized in this study to obtain localization scores for each frequency that were not dependent upon a complex motor skill (underhand throw). Subjects raw kinesthesiometer scores are presented in Appendix D. The means and standard errors for constant error of the kinesthesiometer scores for each of the three frequencies are presented in Table 1.

A minus sign indicated that the subject pointed to the left of the sound source and a plus sign indicated that the subject pointed to the right of the sound source (refer to Figure 3, p. 20). Since constant error is an indicator of the subjects' response bias, the mean scores showed that the 1,000 Hz frequency was 10.19 degrees to the right, the 2,000 Hz frequency was 4.33 degrees to the right and the 3,000 Hz frequency was 3.79 degrees to the left.

To determine if the three treatment frequencies constant error of the kinesthesiometer scores were significantly different from one another a repeated measures design was employed. It can be seen in Table 5 that there was a significant difference between the three frequencies.

Table 5

Analysis for Repeated Measures Design for Constant Error of Kinesthesiometer Scores for Each of the Three Treatment Frequencies

Source	DF	SS	MS	F
Treatment (A)	2	5719.32	2859.66	4.83
Subjects (S)	57	31619.19	554.72	
AS	114	67384.00	591.08	
Total	173	104722.53		

The subsequent Neuman-Keuls post hoc analysis showed that (1) the 3,000 Hz frequency was significantly different from the 1,000 Hz frequency and (2) the 2,000 Hz frequency was not significantly different from either the 1,000 Hz or the 3,000 Hz frequencies.

The kinesthesiometer localization constant error means were compared with the throwing localization constant error means (refer to Table 1, p. 26). An examination of these means showed a similar trend in directional errors. The 1,000 Hz means and 2,000 Hz means were to the right of the sound source and the 3,000 Hz means were to the left of the sound source in both cases. An explanation for the difference in the magnitude of errors between the two tasks may have been the method in which the data was collected. Only one measurement for each frequency was used for the kinesthesiometer data and an average of five scores was used for the throwing localization data. There is less probability of one measurement determining the subjects true score, which could account for some of the difference in the magnitude (due to unreliability). An examination of the kinesthesiometer means shows that the 3,000 Hz frequency was more accurate than the 2,000 Hz frequency. This information does conflict with the trend favoring the 2,000 Hz frequency, but it must be observed that the difference between 4.33 and -3.97 in relation to the target of 0.00 was very small.

The final anslysis concerning the localization data was a correlation between the constant error data for the kinesthesiometer and the mean constant error data for the throwing localization performance. Table 6 shows the constant error means for the kinesthesiometer and the throwing localization scores, the correlation coefficients and the coefficients of determination for each of the three frequencies.

Table 6

Constant Error Correlation for Kinesthesiometer and Localization Scores

Treatment	Kinesthesiometer CE Means	Localization CE Means	Correlation Coefficients	r^2
1,000 Hz	10.19	6.83	.43	.18
2,000 Hz	4.33	0.52	.76	.58
3,000 Hz	-3.79	-3.94	.67	.45

Further, it can be seen in Table 6 that the correlation between the kinesthesiometer localization performance and the throwing localization performance for the 1,000 Hz frequency was relatively low ($r = .43$), accounting for only 18 percent of the variance. The correlation between the kinesthesiometer and throwing localization performance for the 2,000 Hz frequency was the highest of the three correlations ($r = .76$); accounting for 58 percent of the variance. The correlation between the kinesthesiometer and the throwing localization performance for the 3,000 Hz frequency was ($r = .67$), accounting for 45 percent of the variance. The fact that the kinesthesiometer data was based on only one measurement could account for the low correlations. Finally the slightly higher correlations for the 2,000 Hz frequency and the 3,000 Hz frequency supports the superiority of these frequencies over the 1,000 Hz frequency for localization.

Analysis and Results of the Accuracy Data

A subproblem which was of interest was the effect of the three treatment frequencies on accuracy performance. Accuracy performance would depend on localization and also on perception of distance. Perception of distance would be based on the past experience of the subjects, since they had no information regarding this factor in the study.

Subjects' mean accuracy scores for each of the three frequencies are presented in Appendix C. The means and standard errors for the absolute accuracy data are presented in Table 1. An examination of the means indicated that the 3,000 Hz frequency appears to be the most consistent in terms of absolute deviations. To determine if the three treatment frequencies absolute error scores were significantly different from one another a repeated measures design was employed. It can be seen in Table 7 that there was a significant difference between the three frequencies.

Table 7

Analysis for Repeated Measures Design for Accuracy Score Absolute Error Means for Each of the Three Treatment Frequencies

Source	DF	SS	MS	F
Treatment (A)	2	10612.07	5306.03	5.97
Subjects (S)	57	266862.62	4681.79	
AS	114	101282.12	888.43	
Total	173	378756.81		

As a result of the significance indicated by the repeated measures analysis the Neuman-Keuls analysis was employed to determine which frequencies differed from each other. The results showed that the 3,000 Hz frequency was significantly different in accuracy performance from both the 1,000 Hz and 2,000 Hz frequencies. It is concluded that the 3,000 Hz frequency was more consistent than the 1,000 Hz and 2,000 Hz frequencies in terms of absolute deviations. This finding however does not allow us to determine if accuracy or intra individual consistency was responsible for the significant difference or if the significance was due to localization or past experience with throwing at targets.

Subjects' accuracy performance was based upon their localization ability and judgment of distance, which was dependent upon their past experiences. It would be expected then, that any significant differences between accuracy performance and localization performance would be attributed to vertical errors (judgment of distance) since this variable was not controlled. The horizontal errors would be expected to correspond to the localization performance previously presented. Based on these hypotheses the vertical and horizontal components of the accuracy scores were analyzed for constant and variable error.

The constant error means and standard errors for the horizontal component are presented in Table 1. The means show that the 1,000 Hz frequency was 19.98 inches to the right, the 2,000 Hz frequency was 1.77 inches to the right and the 3,000 Hz frequency was 7.90 inches to the left of the sound source. To determine if the three treatment frequencies horizontal constant error scores were significantly different from one another a repeated measures design was employed. It can be seen in Table 8 that there was a significant difference between the three frequencies. However, since the test for homogeneity of covariance was not used and the conservative degrees of freedom approach was used instead, the main effect for the three frequencies was not significant using the conservative degrees of freedom. Therefore the conclusions reached in this section are very speculative and tentative.

Table 8

Analysis for Repeated Measures Design for Horizontal Constant Error of Accuracy Scores for Each of the Three Treatment Frequencies

Source	DF	SS	MS	F
Treatment (A)	2	23251.72	11625.86	3.44
Subjects (S)	57	167677.87	2941.71	
AS	114	384811.43	3375.53	
Total	173	575741.12		

A subsequent Neuman-Keuls analysis indicated (1) the 3,000 Hz frequency was significantly different from the 1,000 Hz frequency, but was not significantly different from the 2,000 Hz frequency and (2) the 2,000 Hz frequency was not significantly different from either the 1,000 Hz or the 3,000 Hz frequency.

An examination of the horizontal constant error means presented in Table 1 indicated that the 2,000 Hz frequency was the closest to the target varying only 1.77 inches to the right of the sound source. The results of the repeated measures and Neuman-Keuls analysis indicated that the 2,000 Hz frequency was not significantly different from either the 1,000 Hz or the 3,000 Hz frequency. The significant difference between the 1,000 Hz frequency and the 3,000 Hz frequency was a result of the subjects' tendency to throw to the right on the 1,000 Hz frequency and to the left on the 3,000 Hz frequency. As was expected the horizontal constant error results for the accuracy data correspond to the constant error results for localization performance. These conclusions must be weighed against the fact that the restrictive assumptions for the repeated measures analysis was not met and the results are only meant to confirm the hypothesis that horizontal errors would reflect localization and vertical errors would reflect past experiences.

The variable error means and standard errors for the horizontal component are presented in Table 1. Variable error was examined to determine if there was any relationship between the three frequencies and the consistency of performance within the individual on the horizontal component. To determine if the three treatment frequencies horizontal variable error scores were significantly different from one another a repeated measures design was employed. It can be seen in Table 9 that there are no significant differences between the three frequencies regarding variable error for the horizontal component.

Table 9

Analysis for Repeated Measures Design for Horizontal Variable Error of Accuracy Scores for Each of the Three Treatment Frequencies

Source	DF	SS	MS	F
Treatment (A)	2	8162456.01	4081228.00	0.75
Subjects (S)	57	443598641.57	7794713.01	
AS	114	617533783.14	5416963.01	
Total	173	1069294880.72		

An examination of the horizontal variable error means presented in

Table 1 (p. 26) indicated that the performance on the 3,000 Hz frequency was the most consistent. The repeated measures analysis showed that this performance is not significantly different from either the 1,000 Hz or the 2,000 Hz frequency. As expected the horizontal variable error results correspond with the localization variable error results.

The constant error means and standard errors for the vertical component are presented in Table 1. The means show that (1) the 1,000 Hz frequency was 3.41 inches from the sound source, (2) the 2,000 Hz frequency was 14.87 inches from the sound source and (3) the 3,000 Hz frequency was 20.92 inches from the sound source. To determine if the three treatment frequencies vertical constant error scores were significantly different from one another a repeated measures design was employed. It can be seen in Table 10 that there was a significant difference between the three frequencies.

Table 10

Analysis for Repeated Measures Design for Vertical Constant Error of Accuracy Scores for Each of the Three Treatment Frequencies

Source	DF	SS	MS	F
Treatment (A)	2	9173.54	4586.77	6.08
Subjects (S)	57	727949.87	12771.04	
AS	114	85965.34	754.08	
Total	173	823088.75		

A Neuman-Keuls post hoc analysis showed that (1) the 1,000 Hz frequency was significantly different from both the 2,000 Hz frequency and the 3,000 Hz frequency and (2) the 2,000 Hz frequency was significantly different from the 1,000 Hz frequency, but not significantly different from the 3,000 Hz frequency.

An examination of the vertical components means presented in Table 1 indicated that (1) the 1,000 Hz frequency mean was the nearest to the sound source (3.41), (2) the 2,000 Hz frequency mean was next (14.87), and (3) the 3,000 Hz frequency mean was the farthest from the sound source (20.92). The subjects' vertical constant error performance appears to indicate that (1) the low frequency (1,000 Hz) was perceived as being closer and (2) as frequency increased (2,000 Hz to 3,000 Hz) the sound was perceived as being further away.

The variable error means and standard errors for the vertical component are presented in Table 1 (p. 26). Variable error was examined to determine if there was a relationship between the three frequencies and the consistency of performance within the individual on the vertical component. To determine if the three treatment frequencies vertical variable error scores were significantly different from one another a repeated measures design was employed. It can be seen in Table 11 that there was a significant difference between the three frequencies.

Table 11

Analysis for Repeated Measures Design for Vertical Variable Error of Accuracy Scores for Each of the Three Treatment Frequencies

Source	DF	SS	MS	F
Treatment (A)	2	4063180.00	2031590.00	5.88
Subjects (S)	57	75626716.50	1326784.50	
AS	114	39351410.34	345187.81	
Total	173	119041306.84		

A subsequent Neuman-Keuls analysis indicated that (1) the 1,000 Hz frequency was significantly different from both the 2,000 Hz and 3,000 Hz frequencies and (2) the 2,000 Hz frequency was not significantly different from the 3,000 Hz frequency. Based on these results is can be stated that there was a trend favoring consistency on the 2,000 Hz and 3,000 Hz frequencies with regard to the vertical component of accuracy performance. An examination of the vertical constant error and variable error means presented in Table 1 (p. 26) indicated that (1) the 1,000 Hz frequency mean was the closest to the sound source and (2) the 3,000 Hz frequency was the most consistent.

Horizontal and vertical absolute error was also presented for comparison with studies that only used this error measurement. Absolute error disregards the sign of the score and represents only the magnitude of the discrepancy from a target. The horizontal absolute error represents the magnitude of the discrepancy from the Y axis. The absolute error means and standard errors for the horizontal component were presented in Table 1 (p. 26). To determine if the three frequencies horizontal absolute error scores were significantly different from one another a repeated measures design was employed. It can be seen in Table 12 that there was a significant difference between the three frequencies.

A Neuman-Keuls post hoc analysis showed that (1) the 3,000 Hz frequency was significantly different from both the 1,000 Hz and 2,000 Hz frequencies and (2) the 2,000 Hz frequency was not significantly different from the 1,000 Hz frequency.

An examination of the horizontal absolute error means in Table 1 (p. 26) showed that the 3,000 Hz frequency has the smallest mean. Based on the

Table 12

Analysis for Repeated Measures Design for Horizontal Absolute Error of Accuracy Scores for Each of the Three Treatment Frequencies

Source	DF	SS	MS	F
Treatment (A)	2	15617.49	7808.74	7.30
Subjects (S)	57	124056.85	2176.43	
AS	114	121896.60	1069.26	
Total	173	261570.96		

repeated measures and Neuman-Keuls analysis it can be concluded that the 3,000 Hz frequency was the most consistent with regard to average absolute deviations from the mean on the horizontal component. This finding corresponded with the localization absolute error data. Unfortunately this error measurement does not allow us to interpret the source of the significance, i.e., greater accuracy or consistency on the horizontal component.

The absolute means and standard error scores for the vertical component are presented in Table 1. To determine if the three treatment frequencies vertical absolute error scores were significantly different from one another a repeated measures design was employed. It can be seen in Table 13 that there were no significant differences between the three frequencies regarding absolute error on the vertical component.

Table 13

Analysis for Repeated Measures Design for Vertical Absolute Error of Accuracy Scores for Each of the Three Treatment Frequencies

Source	DF	SS	MS	F
Treatment (A)	2	406.79	203.39	0.42
Subjects (S)	57	249122.03	4370.56	
AS	114	54111.58	474.66	
Total	173	303640.43		

An examination of the means presented in Table 1 (p. 26) indicated that the performance on the vertical component for the 3,000 Hz frequency was the most consistent with regard to average absolute deviations from the mean. However, the repeated measures analysis has indicated that the 3,000 Hz frequency was not significantly different from either the 2,000 Hz or the 1,000 Hz frequency.

Discussion

Due to the need in the field of physical education for the visually impaired to determine the most efficient auditory cue, when sound localization was necessary for proficient performance, this study was conducted. The present results indicate that none of the frequencies used can be unequivocally recommended as more efficient for localization or accuracy performance for the visually impaired in physical activities on statistical grounds. The localization data in conjunction with the horizontal component of the accuracy performance results did show a trend favoring the 2,000 Hz frequency as being the most efficient for localization.

The results of the vertical component of the accuracy performance indicated that the low frequency (1,000 Hz) was perceived as being closer and as frequency increased (2,000 Hz to 3,000 Hz) the sound was perceived as being farther away. No research could be found to explain this finding. Finally, the present results also indicated that none of the frequencies used can be recommended for the visually impaired for enabling more consistent performance within the individual for localization or accuracy performance on statistical grounds. Upon completing this study there were a number of sources of variance that the investigator feels contributed towards reducing the power of the statistical tests.

(1) A pilot study was conducted on a sixth grade population to establish a criteria for the pretest. A criterion of sixty percent was selected based on the performance of this pilot sample. It was believed that this criteria would discriminate between the accurate and non accurate throwers and still allow for a large sample to be obtained. After administering the pretest to the test sample it was found that they were better skilled then the pilot sample. Therefore a higher criteria could have been used and could have reduced some of the variance on the actual test task. A sixth grade population was selected based on the premise that findings in this area would be most applicable to visually impaired students of this age in physical education. It is now realized that studies investigating sound localization performance on motor tasks are still in the exploratory stages and it would have been more beneficial to have used a larger sample of more highly skilled subjects.

(2) Another source of variance might have been the use of a sighted sample. The findings of several authors, Axelrod (1959), Yates, Johnson,

& Starz (1972), Hare, Hammill, & Crandell (1970) and Simpkins (1971), failed to show any significant differences between the hearing acuity of the visually impaired and normal subjects. These findings showed no significant differences between the visually impaired and normal subjects' ability to discriminate frequency and perceive loudness of auditory stimuli. Lydon and McGraw (1973) have stated that the human ear can be trained for more efficient awareness, identification, localization and discrimination. Having observed the subjects performing the test task, it was felt that a number of the subjects were relatively naive in their ability to localize sound with only their ears. The investigator feels they were accustomed to using their vision along with their ears to localize. The initial stimuli might have been auditory, but they usually relied on their vision to localize the source of the sound. It was felt that this lack of auditory perception training in the sighted sample created a major source of variance in the data.

(3) Whether sighted subjects dealt with the auditory information intramodally or crossmodally could be another source of variance. Intramodal coding involves hearing an auditory cue and responding solely upon auditory information. Crossmodal coding involves hearing an auditory cue and translating it into visual imagery and responding based on this information. Although the subjects never saw the test setting, it is possible since sighted subjects were used that many of them may have tried to translate the auditory input into some form of visual imagery. This crossmodal process might have been used by any number of subjects and was probably not as efficient as the intramodal process (Jones & Connolly, 1970; Diewert & Stelmach, 1977). Congenitally blind subjects do not have visual imagery

to use and therefore would process the information intramodally. The investigator feels that this may be a pertinent variable but an uncontrollable variable when utilizing sighted subjects. This might be a relevant variable for the physical educator to consider when teaching both acquired and congenitally blind students tasks that involve sound localization.

(4) A final source of variance which has already been mentioned is the fact that only one measurement was taken on the kinesthesiometer. There was less probability of achieving the subjects' true response on only one response as opposed to averaging a group of responses. It was possible that the constant error kinesthesiometer data would have correlated higher with the throwing localization data had a number of responses been averaged.

Although, no unequivocal support for any one frequency was obtained from this study some implications can be made from the results for the visually impaired involved in physical recreational activities. The selection of frequencies presently used in audible devices for the visually impaired are not based on scientific information. Reid (1975) has shown that the use of an auditory cue (900 Hz) does improve the motor performance of the visually impaired. The present results show a trend favoring the 2,000 Hz frequency as being the most efficient for sound localization. In terms of absolute deviations from the means the 3,000 Hz frequency was found to be significantly better than the 1,000 Hz frequency. In light of these results, statements of other researchers and considering the lack of research in this area, it is suggested that the 2,000 Hz and 3,000 Hz frequencies be used as audible cues for the visually impaired in physical education tasks involving sound localization over the 1,000 Hz frequency.

The purpose of using auditory aids in physical education for the visually impaired is to improve their motor performance level. This would allow them to participate in physical recreational activities at or near the level of their normal peers. This study did not isolate the optimal frequency for the visually impaired to use when performing tasks involving sound localization. It has laid the groundwork and offered some directions for the physical educator and for further research in this area.

CHAPTER V

SUMMARY AND RECOMMENDATIONS

The purpose of this study was to investigate the effects of three different frequencies on the performance of a sound localization motor task. The subjects for this study were fifty-eight, sixth grade males and females who attended Autumn Lane Elementary School, in Greece, New York. School records were critically reviewed to assure that all subjects had normal hearing, intelligence, and no physical limitations that could effect performance on the test task.

Subjects were randomly assigned a time at which to report to the pre-test area. The pretest involved throwing a fluff ball in an underhand action, for two sets of ten throws at a designated target. The target for the pretest was a strip of rug fifty-six inches long and seven inches wide, which was located on the floor perpendicular and ten feet in front of the prospective subject (refer to Figure 1, p. 15). This task was conducted in a closed off corridor and required approximately three minutes to administer. All subjects in the sample were required to hit the target at least twelve times out of twenty. All subjects were introduced and given instruction as to how to perform the kinesthesiometer task at the completion of the pretest. The test task was explained to all subjects prior to being blindfolded and escorted to the gymnasium by the investigator.

The sound source used in this study was a Wollensak 2520AV cassette player recorder, which emitted the frequencies through an Olson S-453 trumpet speaker. The frequencies were recorded on TDK Super Avilyn cassette tapes. The speaker was located at ground level fifteen feet in front of the throwing board, facing the subject. The speaker was placed on the origin of the X and Y coordinates. The X and Y axises formed four quadrants which were sixteen feet by sixteen feet and were sectioned off into three inch intervals to allow for fast accurate scoring. Swimming goggles, which had the lenses painted with black enamel paint were used as blindfolds. The throwing board was a three foot by two foot "T" composed of two by fours, which was located fifteen feet from the origin and parallel to the X axis (Figure 3, p. 20). Two college students accompanied the investigator and served as aides.

The actual testing was conducted over a period of three consecutive days in the spring, when physical education classes were being conducted outdoors and the gymnasium was available. Each subject was escorted to the gymnasium and placed behind the throwing board and positioned so their throwing arm was directly in line with the Y axis (Figure 3, p. 20).

The actual test involved two tasks. The first task consisted of pointing the kinesthesiometer in the direction the subject thought the sound was coming from. The second task consisted of throwing five test balls in an underhand action at the sound. This procedure was done for each of the three different frequencies (1,000 Hz, 2,000 Hz and 3,000 Hz). The presentation order of the three frequencies was varied randomly from subject to subject. At the completion of these tasks the subjects were lead blindfolded out of the gymnasium. The subjects were then escorted by the investigator back to the pretest area and told that the outcome and details of the study would be explained in a few days.

The localization data was analyzed for absolute, constant and variable error. The kinesthesiometer data was also analyzed for constant error and was correlated with the localization constant error data. The results indicated that (1) the 2,000 Hz and 3,000 Hz frequencies were more significant than the 1,000 Hz frequency and (2) none of the frequencies used enhanced performance consistency over the others. There was evidence of a trend favoring the 2,000 Hz frequency being the most efficient in terms of localization performance.

Accuracy performance was composed of two components: (1) horizontal component, which represents localization performance, and (2) vertical component, which represents judgment of distance. Performance on the vertical component was dependent exclusively on the subjects past experience, since no information was supplied on this variable. Both components were analyzed for absolute, constant and variable error. The horizontal component results paralleled the throwing localization results. The vertical component results showed that the low frequency (1,000 Hz) was perceived as being closer and as the frequency increased (2,000 Hz to 3,000 Hz) the sound was perceived as being further away.

Recommendations for Further Research

Based on the findings of this study, the following directions for further research are suggested:

1. A study should be conducted using a sample that has received training in sound localization.

2. A study should be conducted using a larger, higher skilled and more accurate sample.

3. A study should be conducted using 500 Hz increments and covering a broader range of frequencies (900 Hz to 4,000 Hz). This would hopefully allow clear basement and ceiling levels to be determined around the optimal range for sound localization involving motor tasks.

4. A study should be conducted using a visually handicapped sample.

5. A study should be conducted using other motor tasks.

6. The present study used pure tones at a constant intensity. A study should be conducted using different qualities of the auditory cue, so as to determine the most pleasant and efficient auditory cue.

7. A study should be conducted measuring a number of responses on the kinesthesiometer.

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APPENDICES

APPENDIX A

LIST OF MANUFACTURERS

MAJOR MANUFACTURERS OF AUDIBLE DEVICES FOR THE VISUALLY IMPAIRED

1. American Foundation For The Blind
   15 West 16th Street
   New York, New York

2. American Printing House For The Blind
   1839 Frankfort Avenue
   P.O. Box 6085
   Louisville, Kentucky 40206

3. Bell Laboratories
   600 Mountain Avenue
   Murray Hill, New Jersey 07974

4. Royal National Institute For The Blind
   15 West 16th Street
   New York, New York

5. Science For The Blind Products
   221 Rock Hill Road
   Bala-Cynwyd, Pennsylvania 19004

APPENDIX B

SUBJECTS MEAN LOCALIZATION SCORES
IN DEGREES

SUBJECTS MEAN LOCALIZATION SCORES IN DEGREES

Subject	1,000 Hz	2,000 Hz	3,000 Hz
1	2.00	4.40	6.20
2	55.80	16.80	-94.40
3	6.40	-1.80	-12.00
4	-11.40	-12.80	5.40
5	-12.20	46.20	6.00
6	60.60	-7.80	-25.60
7	-0.40	-28.40	4.80
8	23.20	33.40	-16.40
9	-4.40	12.20	1.20
10	-4.20	-4.80	-2.20
11	7.40	-6.20	-7.00
12	-15.00	-4.00	-14.80
13	7.80	11.80	-11.60
14	-7.00	-5.60	6.60
15	1.00	11.60	-1.20
16	10.00	-5.80	-5.20
17	52.40	55.00	7.20
18	20.00	10.80	-4.40
19	3.40	-20.40	-1.80
20	-19.20	-5.20	-14.00
21	21.20	10.60	2.40
22	-47.00	-18.20	-17.40

SUBJECTS MEAN LOCALIZATION SCORES IN DEGREES

Subjects	1,000 Hz	2,000 Hz	3,000 Hz
23	17.20	-29.00	22.20
24	6.60	-22.20	-4.80
25	-8.20	1.60	12.40
26	-19.80	-3.20	-4.20
27	-5.40	13.60	-12.00
28	17.20	-3.20	5.00
29	21.20	-5.00	2.60
30	9.00	23.40	5.80
31	25.80	7.60	-15.20
32	-0.60	14.20	-1.80
33	24.60	-12.00	-0.80
34	21.80	-10.20	-18.80
35	46.60	4.40	4.60
36	-14.40	-12.80	-32.40
37	30.20	-6.60	-16.80
38	33.60	7.00	1.80
39	-9.00	10.40	1.80
40	-3.40	11.60	-12.40
41	-21.20	16.80	-5.20
42	5.40	-7.20	-9.80
43	35.00	-2.80	-2.20
44	-29.00	14.60	2.40

SUBJECTS MEAN LOCALIZATION SCORES IN DEGREES

Subjects	1,000 Hz	2,000 Hz	3,000 Hz
45	6.00	-12.80	6.60
46	14.20	-1.60	8.20
47	21.40	-14.60	17.20
48	40.60	-18.40	4.20
49	10.00	6.60	-4.60
50	-55.60	32.00	22.80
51	16.80	-9.20	2.60
52	-4.40	-0.20	-15.60
53	4.20	4.20	7.00
54	-0.40	-22.40	1.00
55	-4.80	-4.60	-12.20
56	19.00	-4.60	1.20
57	-6.20	-4.60	7.40
58	1.80	-22.00	-8.60

APPENDIX C

SUBJECTS MEAN ACCURACY SCORES
IN INCHES

SUBJECTS MEAN ACCURACY SCORES IN INCHES

Subject	1,000 Hz	2,000 Hz	3,000 Hz
1	21.21	43.83	38.87
2	148.61	51.31	259.13
3	24.21	17.20	40.29
4	68.93	65.03	71.08
5	91.43	173.22	103.86
6	158.13	136.67	139.13
7	71.67	90.63	44.23
8	75.37	102.73	112.45
9	45.00	51.39	28.36
10	90.95	96.17	57.95
11	26.29	20.59	28.25
12	94.30	67.33	81.94
13	38.89	62.01	53.18
14	75.50	61.95	56.43
15	23.53	56.93	42.91
16	177.25	180.29	140.53
17	149.51	161.79	31.79
18	82.36	70.89	66.15
19	91.45	96.97	94.71
20	126.49	61.36	78.93
21	77.80	80.05	50.87
22	162.83	140.79	111.97

SUBJECTS MEAN ACCURACY SCORES IN INCHES

Subject	1,000 Hz	2,000 Hz	3,000 Hz
23	54.51	93.65	68.81
24	84.18	104.65	90.71
25	54.39	73.53	69.61
26	92.00	62.63	55.23
27	54.81	90.55	76.81
28	155.60	132.88	108.17
29	66.36	41.19	35.93
30	39.57	95.81	33.23
31	84.31	36.73	44.11
32	24.03	83.73	25.27
33	87.45	48.90	8.46
34	102.07	110.31	131.36
35	151.33	21.25	26.41
36	125.75	96.67	144.48
37	90.37	47.65	81.11
38	180.39	185.81	80.97
39	89.23	70.67	81.03
40	33.77	48.27	50.91
41	93.15	122.19	93.15
42	77.24	78.13	37.34
43	114.99	74.58	34.75
44	117.99	112.11	108.47

SUBJECTS MEAN ACCURACY SCORES IN INCHES

Subjects	1,000 Hz	2,000 Hz	3,000 Hz
45	120.99	158.95	141.50
46	49.83	29.81	36.07
47	241.47	179.10	167.19
48	130.05	109.74	39.95
49	52.51	41.43	79.01
50	197.01	106.37	81.82
51	59.59	52.15	20.67
52	99.73	88.61	73.81
53	122.49	126.13	114.33
54	18.38	68.44	18.85
55	26.79	110.91	46.53
56	165.11	166.37	163.95
57	93.36	42.23	39.51
58	76.11	91.11	43.63

APPENDIX D

SUBJECTS KINESTHESIOMETER SCORES
IN DEGREES

SUBJECTS KINESTHESIOMETER SCORES IN DEGREES

Subject	1,000 Hz	2,000 Hz	3,000 Hz
1	12	14	07
2	-20	25	-80
3	09	01	-10
4	-05	-14	20
5	-22	38	-16
6	35	00	-15
7	36	-18	32
8	43	45	-34
9	-23	10	-05
10	-35	10	05
11	-05	00	-05
12	25	21	-15
13	05	25	-16
14	-11	35	09
15	20	35	-06
16	15	-10	-15
17	50	60	00
18	20	30	-02
19	11	-17	-20
20	-30	-02	-05
21	55	27	-08
22	87	-30	15

SUBJECTS KINESTHESIOMETER SCORES IN DEGREES

Subject	1,000 Hz	2,000 Hz	3,000 Hz
23	09	-24	-39
24	-06	-33	-40
25	05	04	13
26	-76	-11	-02
27	05	20	-20
28	16	-05	01
29	50	-06	10
30	-06	15	09
31	27	18	-26
32	05	11	-09
33	24	-19	00
34	35	-10	-32
35	30	10	-05
36	-14	-04	-20
37	27	05	-16
38	25	50	-05
39	-05	10	05
40	13	32	09
41	-13	35	-11
42	-28	-16	10
43	45	15	03
44	11	09	-04

SUBJECTS KINESTHESIOMETER SCORES IN DEGREES

Subject	1,000 Hz	2,000 Hz	3,000 Hz
45	30	-10	15
46	14	-01	12
47	27	-25	21
48	55	-22	15
49	16	00	-12
50	-50	30	33
51	24	-03	20
52	40	02	-19
53	-26	10	14
54	05	-19	-04
55	-14	-80	-09
56	29	-11	04
57	-15	05	08
58	05	-16	15